

A REVISION OF MARS SEISMICITY FROM SURFACE FAULTING

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An estimate of the present day shallow seismicity of Mars was made by measuring the total slip on faults visible on the surface of the planet throughout geologic time [1]. Calibration of these results with estimates based on surface structures on the Moon and measured lunar seismicity that includes the entire seismogenic lithosphere indicates that Mars is seismically active today, with a sufficient number of detectable marsquakes to allow seismic investigations of the interior of Mars.

The relative geologic histories of the terrestrial planets suggests that Mars should be seismically more active than the Moon, but less active than the Earth [e.g., 2]. The seismic scalar moment is defined as $M_o = \mu S A_f$, for average slip S over fault area A_f , and uniform rigidity μ . Measuring the total slip on a fault of known or estimated depth and length allows a determination of the cumulative seismic moment, which provides an estimate of the total seismic energy released by simple double-couple source mechanisms. Fault area and slip were estimated for extensional and compressional structures observed in Viking images and the cumulative moment calculated for 4 periods of tectonic deformation on Mars [1]. The total moment release per year was greatest during the earliest period of Tharsis deformation and decreased through time to the most recent period. The decrease in total moment release rate appears to follow an exponential decay toward the present, which is expected if seismicity is governed by simple lithospheric cooling. An exponential extrapolation to the present argues that Mars is nearly as seismically active today as it has been for the entire Late Amazonian. On Earth, most earthquakes occur without surface breaks. A similar calculation was made for the Moon, where results can be compared directly with measured seismicity and moment release for the entire seismogenic lithosphere. This calculation indicated the total present moment release rate for the entire lithosphere on Mars (including events on blind faults that do not break the surface) is about 10^{25} dyne-cm/yr, which is 3 orders of magnitude higher than estimated from surface faulting alone [1]. This observationally based estimate also agrees with theoretical lithospheric cooling calculations for Mars [2] and is between the present total moment release rate for the Moon (10^{22} dyne-cm/yr) and the Earth (10^{29} dyne-cm/yr), as would be expected from a simple comparison of the level, duration, and present geologic and tectonic activity of the two planets. The release of the total seismic moment was distributed according to event size by assuming a relation between moment and frequency of occurrence based on intraplate oceanic events. These estimates suggest about 14 teleseismic events and more than a hundred equivalent magnitude 3 or larger earthquakes on Mars would be expected each year, which is a promising prospect for future seismological investigations [1].

This previous estimate is subject to revision due to advances in the following three aspects of the assessment. First, much better control of the age of structures is known and a much more extensive database of structures exists [3]. Detailed mapping of over 25,000 extensional and compressional structures in the established stratigraphic framework of Mars shows that they formed during 5-6 main stages beginning in the Noachian and extending through the Amazonian [3], which is a substantial improvement in number (3 times more) and age determination (6 age periods versus 4) over previous estimates of changes in moment release through time. Second, new aspects about the subsurface geometry of many of the structures has been proposed allowing a better estimate of the depth extent of the faults, which in most cases will increase the moment release. Finally, there is much more information on moment release from earthquakes on well studied structures on the Earth that could allow an independent means of deriving moment release from individual structures and constraining the maximum marsquake likely [e.g., 4]. The maximum marsquake is important in determining how the total moment release is distributed on smaller marsquakes and their recurrence rates. All of these changes are likely to increase the total estimated present day seismic moment release and seismicity above the 10^{25} dyne-cm/yr estimated previously, but still below that for the Earth.

References:

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